CARBON NANO-TUBE REINFORCED ALUMINUM COMPOSITE MATERIAL

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Inventor(s): ISHIDA YOICHI; ITO KUNIO; KUZUMAKI TOORU
Applicant(s): UNIV TOKYO
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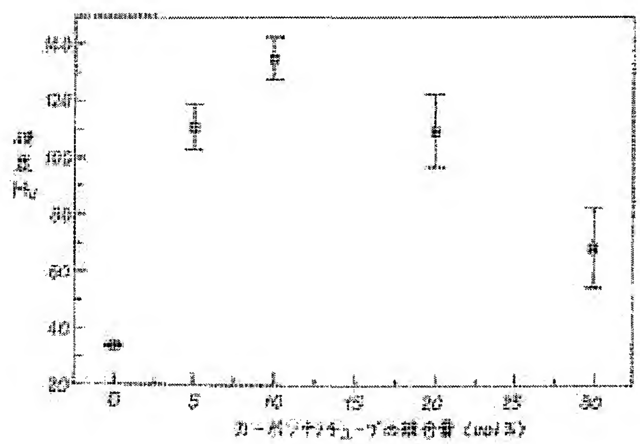
Abstract of **JP 10088256 (A)**
PROBLEM TO BE SOLVED: To obtain an aluminum composite material capable of being easily worked into arbitrary shape by compounding specific amounts of reinforcement consisting of a mixture of carbon nano-tube and carbon nano-capsule with a matrix composed essentially of aluminum.
SOLUTION: A carbon rod is subjected to D.C. are discharge in a helium atmosphere, by which cylindrical deposits, consisting of 50-95vol.% carbon nano- tube and 5-30% carbon nano-capsule, are formed on the cathode side. There deposits are added as reinforcement by 5-30vol.% to a matrix composed essentially of aluminum and dispersed sufficiently, and then, plastic working, such as drawing, swaging, and compression forming, is performed at ordinary temp., by which a composite material is formed.; By this method, the carbon nano-tube reinforced aluminum composite, material capable of being easily worked into arbitrary shape can be obtained.



CLAIM + DETAILED DESCRIPTION

[Claim(s)]
[Claim 1] The reinforcing material which consists of a mixture of the carbon nanotube and carbon nano capsule which were compounded in the matrix which makes aluminum the main ingredients, and said matrix is contained. The carbon nanotube strengthening aluminum composite material characterized by compounding said reinforcing material in 5-30 volume % to said matrix.
[Claim 2] As for the mixed ratio of a carbon nanotube and a carbon nano capsule used as a reinforcing material, in 50-95 volume % and a carbon nano capsule, a carbon nanotube is the carbon nanotube strengthening aluminum composite material to which it is characterized by mixing in the range of 5-30 volume %.

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention is the carbon nanotube strengthening aluminum composite material compounded with the aluminum matrix by using a carbon nanotube and a carbon nano capsule as a reinforcing material, and belongs to a carbon fiber strengthening metal composite material.
[0002] The products which can apply this invention are power lines, such as a structure member in the place which needs light weights, such as transport dexterous structure material and aerospace industry, and interior wiring (spacecraft etc.).
[0003]
[Description of the Prior Art] Although various systems are examined as a composite material which combined a fiber and metal, as for the carbon fiber strengthening metal (CFRM) which aimed at high specific tensile strength and high elasticity also in MMC, the aerospace

development fields, such as a spacecraft, are begun, and the development is strongly desired from energy, a telecommunications sector, etc.

[0004] Although most carbon fiber strengthening aluminium alloys are examined as CFRM characterized by a light weight and high intensity an old place, even if many of the researches call it the research on control of an interface reaction, they are not an overstatement. Degradation of the fiber it is shown clearly experimentally that the interface dynamics characteristic of a composite material influences the macroscopic characteristic of material, and according to the interface reaction of carbon fiber and the aluminium alloy of a matrix especially, It is because how formation of a reaction product is controlled causes improvement in the dynamics characteristic of a composite material.

[0005]

[Problem to be solved by the invention] If carbon fiber / aluminum system composite material is below 500 ** under non-oxidizing atmosphere, strength reduction will not be accepted even if it performs heating maintenance. However, when retention temperature becomes more than 550 **, it is aluminum4 C3 by the interface reaction of carbon fiber and a matrix. While it is formed and the cross-section area of carbon fiber decreases, intensity falls according to the notch effect in the origin of this carbide. Moreover, it is shown clearly by old research that heating in the atmosphere poses a problem with serious degradation of the carbon fiber by oxidization.

[0006] Although control of the interface reaction by the addition element to the metal plating and the ceramic coating ** matrix to ** carbon fiber surface is mainly tried as these measures, the room of examination is still left behind by improvement on an industrial level from the problem of productivity etc.

[0007] Although the carbon fiber used industrially now has the structural difference of some, such as a PAN system and a pitch system, it has crystallographic anisotropy similar to graphite fundamentally like a common solid carbon material. therefore, the surface (001) Basal surface (100) represented in a field the prism side of the zigzag type arrangement of the carbon atom represented in a field -- and (110) The prism side of the armchair type arrangement represented in a field exists. the surface free energy of a basal surface -- the ratio of 0.141 / m2, and a prism side -- surface energy -- 4.81/m2 ** -- according to [it is reported and] this -- the surface free energy of a graphite crystal -- a basal surface -- the direction of a prism side -- 3.1 twice -- large. Therefore, when the fiber constituted by the graphite bottom where the carbon fiber surface is perfect is used, it seems that it is effective for control of a reactional phase. As for this, the directions of high elasticity carbon fiber with the actually high degree of graphite-izing are that there are comparatively few amounts of generation of a reactional phase, and aluminum4 C3 which is a reactional phase. It is clear also from being observed to have grown to be epitaxial from the prism side of a fiber.

[0008] The carbon fiber of coexistence is classified into some kinds from a manufacturing

process, structure, and mechanical properties, and is used according to the purpose. However, it is clear for graphite-ization not to be said to be completeness in which kind of carbon fiber, but to have crystallographic anisotropy. Therefore, when metal is made into a matrix, always in consideration of control of the interface reaction between a fiber/matrix, to take a measure has been needed for generation of a reactional phase.

[0009]

[Means for solving problem] Thought, in order that this invention might solve the above-mentioned technical problem, and this invention contains the reinforcing material which consists of a mixture of the carbon nanotube and carbon nano capsule which were compounded in the matrix which makes aluminum the main ingredients, and said matrix. Said reinforcing material is in the carbon nanotube strengthening aluminum composite material compounded in 5-30 volume % to said matrix.

[0010] As for the mixed ratio of a carbon nanotube and a carbon nano capsule used as a reinforcing material, in the composite material of this invention, it is desirable that 50-95 volume % and a carbon nano capsule are mixed by the carbon nanotube in the range of 5-30 volume %.

[0011] In this invention, the Reason for ingredient range limitation is as follows.

(1) The data that the amount of composites of a reinforcing material serves as a peak from;-experiment near 10% about the range of the amount of composites of a reinforcing material is shown in drawing 1 . At 5% or less, since the number of the carbon nanotube contributed to strengthening decreases, the influence of the interaction of the fiber / matrix interface given to the character of the whole material is small, and the compound effect is considered to be hurt by the character of the aluminum which is a matrix. Moreover, especially at 30% or more, it is thought that there is a place which does not form the fiber / matrix interface in such a place as condensation-ization of reinforcing materials has taken place. With a forming object, especially, a crack is produced from the bad portion of such adhesiveness or adhesion nature, and it seems that the fall of the fabrication nature and the sintering nature of a complex is caused as a result. From this experiment, it was judged that the amount of composites beyond this was not suitable.

[0012] (2) Although characterized by using a carbon nanotube as a reinforcing material by;-this invention about the carbon nanotube of a reinforcing material, and the rate of the carbon nano capsule, it confirmed that content of a carbon nano capsule is also effective not only to a nanotube but to others. That is, it is thought that a carbon nanotube can be used as a fabric reinforcement phase, and a carbon nano capsule is applicable to transposition theory strengthening of an aluminum matrix as a particle distribution reinforcement phase. Although the method of vanishing a carbon nano capsule by heat treatment etc. until now, and refining a carbon nanotube in 99% or more of purity is announced By this method, since a possibility of

also damaging a carbon nanotube simultaneously was high and an activity field produced chemically by heat treatment in this invention, I thought that it was not suitable. Moreover, it has the problem in the case of using industrially -- the quantity refined decreases extremely to materials. The way used as a reinforcing material judged substantially the mixture of the carbon nanotube obtained from these Reasons by a simple refining process, and a carbon nano capsule to be effective.

[0013]

[Working example] The composite material of this invention is produced as follows, for example. The reinforcing material which consists of 50-95 volume % of carbon nanotubes of the specified quantity and a mixture with 50-5 volume % of carbon nano capsules to the end of aluminium powder is added, and it is made to fully distribute. Next, drawing out, SUEJINGU, compression molding, etc. carry out the plastic processing of such a composite material in normal temperature, and a composite material is obtained in forms, such as a stick, a board, and a section bar.

[0014] An example is shown below. The cylindrical sediment was produced in the negative pole side by carrying out direct-current arc discharge of the carbon stick in helium atmosphere. The mixture (about 40-60 volume % and 60-40 volume % of carbon nano capsules are included for a carbon nanotube) of a carbon nanotube and a carbon nano capsule was obtained from the inside. Next, the reinforcing material was added in the end of the aluminium powder of purity 99.99 % and about 0.1 micrometer of particle diameter, and this was fully distributed. The aluminum sheath was filled up with the mixed powder obtained after this, and multicore line-ization by drawing-out processing was attained. After wire-rod-izing, the carbon nanotube strengthening aluminum composite material made into the purpose was obtained by heat-treating in a vacuum (- 10-2Torr) (330 **, 30 minutes).

[0015] In this invention, it is important to make into the suitable range the amount of composites of the reinforcing material which consists of a mixture of the above-mentioned carbon nanotube and a carbon nano capsule, and to an aluminum matrix, as shown in drawing 1 , the above-mentioned reinforcing material is compounded in 5-30 volume %. If the significant compound effect is not acquired but 30 volume % is exceeded with the amount of composites of a reinforcing material being less than 5 volume %, for example, the fabrication nature of a complex cannot fall sharply, and a practical complex cannot be obtained. Drawing 1 is the figure showing the amount of composites of a carbon nanotube (volume %), and change of minute hardness. It was confirmed that 10 volume % is the best as for the amount of composites of a carbon nanotube as shown in drawing 1 .

[0016] As for the mixed ratio of the carbon nanotube in the above-mentioned reinforcing material, and a carbon nano capsule, it is desirable to set up so that the volume ratio of a carbon nanotube may serve as a range which are 50-95 volume % and 50-5 volume % of

carbon nano capsules. Moreover, also when a thing [the diameter per one / in about 5-60nm] about 0.5-5 micrometers long is desirable and has become a two or more bunch as a carbon nanotube to be used, it can use.

[0017] As a result of observing the organization of a carbon nanotube strengthening aluminum complex, as shown in drawing 3 , while the carbon nano capsule was distributing uniformly in the matrix, the organization where the carbon nanotube improved for ** to the drawing-out direction by super-thin line-ization was observed. Moreover, when a carbon nanotube was used, even if heat-treated, generation of the reactional phase was not accepted, but there was no corrosion of a fiber etc.

[0018] The result of having done a hardness examination and tensile test of the carbon nanotube strengthening aluminum composite material under room temperature is shown in drawing 1 and drawing 2 . Hardness was able to increase about 2 to 5 times with the increase in the amount of composites, and the mechanical properties (breaking strength) of aluminum were able to be raised by compounding a carbon nanotube and a carbon nano capsule as a reinforcing material so that more clearly than a figure. Moreover, since the carbon nano capsule was distributing uniformly in the matrix, it became clear that the decreasing rate of the hardness after heat treatment had contributed to strengthening of a matrix small. 560 Even if held by ** for 24 hours, reactional phase generation was not accepted in a fiber / matrix interface, but it was checked that the problem of material is conventionally [using carbon fiber] conquerable.

[0019] [The example of an examination]

[Objects of the Invention] Although it can be regarded as a kind of mustached crystal from the unique structure, a nanotube will cause the unique plastic deformation of a style accompanied by buckling, if strong processing is given. Moreover, it is thought that it is inactivity chemically since the surface of the nanotube is surrounded by the graphite bottom. Therefore, a nanotube may be able to be used as new textile materials equipped with quantity specific tensile strength and modification ability from now on. By this research, the material which compounded the nanotube with the aluminum matrix was made as an experiment, and the detailed organization and mechanical property of its fiber / matrix interface were examined.

[0020] [Test method] The nanotube was produced by the arc discharge method. Granular graphite and amorphous carbon are contained in the used nanotube powder as impurities. Production of the sample was performed by SUEJINGU, after filling up the aluminum sheath with the mixed powder to which the loadings of nanotube powder were changed with 0 to 30 weight % in the end of aluminium powder (particle diameter 0.1 [about] purity 99.99 %, mum), respectively and sintering in 600 ** and 60 minutes. The result which complex tissue observed with the JEM-200 CX high resolution electron microscope is as being shown in drawing 4 , and evaluated the mechanical property by the minute hardness examination and the tensile test.

[0021] [Result] The sample suited the tendency which hardness increases with the increase in the amount of composites of a nanotube. When organization observation was performed, much granular graphite was observed with the nanotube so that more clearly than drawing 4 , and it was surmised that this had also contributed to strengthening of a matrix. Moreover, even if held at the temperature more than 550 ** for a long time, in the nanotube / aluminum interface, generation of the reactional phase was not accepted but the surface coat of the nanotube was stable. Since the nanotube had taken the structure which cannot form a reactional phase easily theoretically, unless the prism side produced it by fracture etc., it was confirmed that it is effective also as a compound material in metal matrix composite.

[0022]

[Effect of the Invention] [the aluminum composite material strengthened with the carbon nanotube and the carbon nano capsule] Since manufacture of the composite material by the difficult plastic processing is attained and the surface of the nanotube is moreover chemically surrounded on the stable graphite bottom when the existing carbon fiber is used, generation of the reactional phase by the interface reaction at the time of heat treatment can be controlled. For this reason, processing to arbitrary form is able to raise an easy and practical temperature region compared with material conventionally.

[0023] This invention which uses a nanotube as strengthening textile materials manufactures the composite material which does not produce a reactional phase in an interface taking advantage of the structural feature of the nanotube chemically surrounded by the stable graphite bottom. By using a nanotube as textile materials, processes, such as coating conventionally needed at the time of composite material manufacture, can be skipped, and reduction of manufacture cost can also be expected.

[0024] Since a reaction product is not formed in an interface even if the aluminum with which this invention compounded the carbon nanotube and the carbon nano capsule as a reinforcing material has the small decreasing rate of the hardness after heat treatment and it performs high temperature and prolonged maintenance, the mechanical properties of a composite material do not deteriorate rapidly. Even if it performs plastic processing, such as compression and extrusion, at the time of composite material manufacture and use, in order to carry out plastic deformation of the nanotube, it is not fractured easily and does not produce a defect inside.

[0025] For this reason, the composite material manufactured by this invention has the advantage which can perform use to aerospace industries, such as a spacecraft, an energy industry, etc. and which becomes industrially in size as a light weight and a high intensity structure material.

[Translation done.]